C11 Falsework design

C11.1 General

C11.2 Falsework and forms

C11.2.1 General

C11.2.1.1 Policy overview

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C11.2.2 Load application

The construction wind load of 50 psf (2.4 kPa) for a 100 mph (161 kph) wind speed at heights to 30 feet (10 m) is the same as the wind load specified during construction of PPCB [BDM 5.4.2.2.5] and CWPG bridges [BDM 5.5.2.2.6]. That load is conservative because it was taken by the office to be the same as the permanent wind load for bridges during service as given in the AASHTO Standard Specifications [AASHTO 3.15].

If the falsework construction wind load were taken from the *AASHTO Guide Design Specifications for Bridge Temporary Works* for non-heavy-duty shoring systems, the wind speed map would indicate 80 mph (129 kph) or less [AASHTO-Temp Figure 2.1]. The load for the lowest height zone to 30 feet (10 m) then would be 20 psf (960 Pa) or less [AASHTO-Temp Table 2.2].

The formwork construction wind load may be even less, set at a minimum of 15 psf (720 Pa) by the AASHTO guide [AASHTO-Temp 3.2.3].

Even though the formwork and falsework wind load given in this article [BDM 11.2.2] is conservative, the office prefers to require the load so as to ensure lateral stability of the falsework. In some cases it may be difficult to evaluate other lateral loads, but in any case the designer needs to consider the largest load.

C11.2.3 Service load groups

The AASHTO guide refers to the *National Design Specification for Wood Construction* (NDS) for modification factors for wood structural components [AASHTO-Temp 2.1.3.2], but also lists a percentage of allowable stress of 133% for Load Groups III and IV that would further increase allowable stresses [AASHTO-Temp Table 2.3]. The 133% increase should be neglected for wood structural components; the office requires that the allowable stresses be adjusted for load duration factors instead of the percentages of allowable stress.

ACI's *Formwork for Concrete* makes a distinction between wood formwork for limited reuse that may be designed as a temporary structure and wood formwork with considerable reuse that should be designed as a permanent structure. The distinction affects the load duration factor and has the effect of lowering allowable stresses for the considerable reuse condition. For typical bridge projects the designer may assume limited reuse.

Generally the AASHTO guide [AASHTO-Temp C2.1.3 and 2.1.3.2] and ACI's *Formwork for Concrete* consider 1.25 as the appropriate load duration factor for wood formwork and falsework under dead and live loads and consider the condition of lumber and timber members to be dry. The authors of NDS formwork examples argue for different conditions. For plywood they use a load duration factor of 1.45 rather than the APA combined load duration and experience factor (or concrete setting factor) of 1.625. The 1.45 factor is associated with a one or two hour concrete set, whereas 1.625 is about the same as the wind factor of 1.60 associated with a 10-minute period. The authors also use the 1.45 load duration factor for studs and wales and consider those members to be in a wet use condition. Although the NDS example authors have reasonable arguments the office prefers the more conventional AASHTO and ACI use of load duration and wet use factors.

C11.2.4 Analysis and design

C11.2.4.1 Analysis

C11.2.4.2 Allowable stresses

C11.2.4.2.1 Plywood sheathing

C11.2.4.2.2 Board sheathing

C11.2.4.2.3 Dimension lumber and timber

The allowable stresses for dimension lumber and timber vary widely with size or use category, species, grade, and adjustment factors. In the past falsework has been designed and checked on the basis of allowable stresses published in the Iowa DOT Standard Specifications, unless the contractor certified a higher grade. At the time many years ago when the allowable stresses were determined, the species groups available locally often were douglas fir-larch and southern pine, for which the stresses were intended. However, there have been significant changes in recent years. First, the design values in the *National Design Specification for Wood Construction Supplement* (NDS Supplement) have been revised significantly downward or upward in some cases, and the revisions are most apparent for timber. Second, spruce-pine-fir (SPF) now, depending on U.S.-Canadian trade relations, is one of the more commonly available species groups in Iowa, and the species group typically has lower design values than douglas fir-larch or southern pine. Periodically there are other species groups available with even lower design values. Based on the discussion above, the design values in the Iowa DOT Standard Specifications have been revised to account for revisions to the NDS Supplement and use of SPF in formwork and falsework.

C11.2.4.2.4 Steel

C11.2.4.2.5 Piles

Pile design in the Office of Bridges and Structures has transitioned from allowable stress design (ASD) to load and resistance factor design (LRFD) but, because the *AASHTO Guide Design Specifications for Bridge Temporary Works* remains an ASD guide, falsework piles should be designed by the ASD method. The designer should be aware of two issues: allowable bearing values based on type of soil and allowable driven bearing values determined by formula.

In the past allowable unit pile bearing values for typical soil types that were used to estimate the required pile length were obtained from *Foundation Soils Information Chart, Pile Foundation,* a publication of the Soils Design Section commonly called the “Blue Book”. If this publication is not available, use the following work-around:

(1) Print the LRFD nominal geotechnical resistance tables in the pile section [BDM Tables 6.2.7-1 and 6.2.7-2].
(2) Select kips or ksi end bearing values and kips/foot friction bearing values appropriate for the soils at the falsework site.
(3) Correct the LRFD resistances to ASD bearing values by dividing by 4. The divisor adds a safety factor of 2 and changes the units from kips to tons. Allowable end bearing values then will be in tons or tons/square inch, and allowable friction bearing values will be in tons/foot. (For steel H-piles the Blue Book end bearing values were given inconsistently in psi.)

Example: A wood pile in cohesive material with a mean N_{60}-Value of 20

(2) Select 24 kips (LRFD end bearing resistance)
(3) Divide by 4: 6 tons (ASD end bearing)

Example: A steel HP 10x57 in cohesive material with an N_{60}-Value of 50

(2) Select 4 ksi (LRFD end bearing resistance)
(3) Divide by 4: 1 ton/square inch (ASD end bearing to be multiplied by pile cross sectional area)

Typically piles are driven with construction control either by wave equation analysis (WEAP) or by formula. If WEAP software is to be used to develop driving graphs for falsework piles, the input should include a safety factor. For production piles the Office of Construction used a safety factor of 2.2, and that same factor may be used for falsework piles.

Driving formulas are given in the Iowa DOT Standard Specifications [IDOT SS 2501.03, M, 2]. Although the 2012 Standard Specifications had ASD formulas, the formulas will be converted to LRFD by multiplying the numerator constants by 4 at some time after 2012. The English ASD numerator constants, in order for the four formulas are: 3, 4.5, 3, and 7. The English LRFD constants in the same order will be 12, 18, 12, and 28. After the Standard Specifications are revised, the falsework designer working in ASD will need to divide the numerator constant in the appropriate formula by 4.

The allowable load for timber piles has varied in Iowa DOT specifications and documents. The maximum allowable bearing value of 20 tons given in the BDM article [BDM 11.2.4.2.5] generally is consistent with Iowa DOT guidelines for short piles. For falsework the contractor normally will be using short piles, and thus the 20-ton guideline fits typical construction practice. The ASD 40-ton driving limit in the 2012 Iowa DOT Standard Specifications [IDOT SS 2501.03, O, 2, c] is intended to prevent overdriving damage to piles.

For many years it has been office practice to require sway bracing for pile bents when their height is more than 10 feet (3 m). Without sway bracing for lesser heights, however, it is possible that piles will not be embedded sufficiently to carry lateral loads of the falsework, especially if minimum embedment length is not shown on the falsework plans. In order to ensure that the designer considers lateral loads, the Iowa DOT Standard Specifications and several BDM articles have been revised to require that the minimum embedment length be shown on the falsework plans.

C11.2.4.2.6 Soils

C11.2.4.3 Section properties

C11.2.4.4 Design

C11.2.5 Detailing

C11.2.6 Plan review

C11.2.6.1 Plan checklist

C11.2.6.2 Design review checklist

C11.2.6.3 Reviewed copy distribution